July 2004

Urban Ecosystem Analysis Montgomery, AL

Calculating the Value of the Urban Forest

Report Contents

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Project Overview

AMERICAN FORESTS, in conjunction with Federal, State, and local partners, analyzed the effects of 16 years of changing landcover in Montgomery, Autauga, and Elmore Counties, Alabama. The results demonstrate the environmental impacts of tree loss on the cost of managing air quality and stormwater runoff, while providing local communities with important information and tools for planning and decision making.

The analysis covered more than 1.3 million acres (2,060 square miles) of the three counties. In addition to a time sequence analysis of the changing landcover using Landsat satellite imagery, a detailed assessment of the City of Montgomery's tree cover was also conducted using high-resolution multispectral satellite imagery. This digital data—a "green data layer" allows the City to address their community development and revitalization issues on a daily basis. While this report highlights tree cover trends and provides an overview of the area's ecological benefits, the digital data provided along with this project allows the City to incorporate green infrastructure into their Geographic Information Systems (GIS) database to use in planning. The International City/County Management Association (ICMA) recognizes that trees provide essential ecosystem services and recommends setting tree canopy goals as an effective green infrastructure public policy (ICMA-IQ Report, Nov. 2002).

For the analysis, the city was divided into subwatersheds, council districts, and the riverfront master plan areas. The analysis used GIS technology to assess the urban landscape and to model the effect of the landcover on air quality and stormwater movement.

In the City of Montgomery's Comprehensive Urban Forestry Plan (2002), the goals for trees include, "Incorporate, manage, and protect trees as a component of the city's infrastructure." The plan identified individual tasks including revising the planning, zoning and landscape ordinances, and developing a tree ordinance.

The city of Montgomery is located on the banks of one of the largest rivers in the state; the Tallapoosa River joins the Alabama River which flows along the north western edge of the city. This river provides a strong regional connection, both visually and ecologically. Montgomery's drinking water comes from the Tallapoosa River. A portion of Montgomery's watershed recharge zone is located in Elmore county thus regional development should be coordinated closely on a watershed basis, since Montgomery's drinking water depends on it.

The city is growing on the eastern side and along the area identified in the Riverfront Master Plan, currently under redevelopment. This growth has exacerbated existing flooding and drainage issues the city faces. There is also a sprawl pattern of development as farmland is being converted to light industry and new corporate headquarters. There are some prime opportunities to regain open space and build green infrastructure back into the city, as industrial sites are being redeveloped into recreation areas along the riverfront. Other opportunities to reclaim open space exist in some neighborhoods within the city that have vacant lots.

The challenge to the community is how to manage growth and foster mixed-use development while balancing green and gray infrastructure. Using the data from this study, planners will have the tools they need to manage, maintain, and balance the natural environment with the built one.

The study produced a rich data set describing the environment. The data coupled with its relevance and accessibility to those working at the local level, offers the opportunity for much better land use and development decisions than in the past. These data provide an important new resource for those working to build better communities—ones that help meet federal clean water and air regulations, are more cost effective to operate, and provide a healthy environment for its citizens.

Major Findings

In Montgomery, Autauga, and Elmore Counties, AMERICAN FORESTS used Landsat TM imagery (30-meter resolution) satellite imagery to measure different land cover types (trees, open space, water, urban etc.) and to calculate the impact of each on air and water. A more detailed analysis of the City of Montgomery was conducted using high resolution imagery (4 meter resolution) from 2002. The City can incorporate this data into its decision making.

The Tricounty Area's urban forest provides ecological benefits for managing stormwater and mitigating air pollution.

■ As of 2002, using Landsat satellite imagery, the tricounty area is comprised of 614,678 acres of tree canopy (47%), 453,299 acres of open space (34%), 117,581 acres of impervious surfaces (9%), 93,151 acres of bare ground (7%), and 39,839 acres of water (3%).

■ Between 1986 and 2002, the tricounty area lost 7% of its tree cover. Over that same time period, the area's impervious surfaces increased by 4%.

■ While the overall percentages did not change dramatically, lost ecosystem services were significant because the area is large—covering 1.3 million acres. Stormwater retention capacity decreased by 319,000 cubic feet, a loss valued at $638,000.[1] The ability of trees to absorb an additional 8.9 million pounds of air pollutants annually was also lost and valued at $22 million each year.[2]

■ As of 2002, the total stormwater retention capacity of this urban forest is 3.3 billion cubic feet. Without these trees, the cost of managing the increase in stormwater runoff would be approximately $6.6 billion (based on construction costs estimated at $2 per cubic foot).

■ Urban forests provide air quality benefits by removing nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone, and particulate matter of 10 microns or less. The tricounty area's urban forest removes 58.6 million pounds of pollutants from the air each year—a benefit worth $144 million annually.

The City of Montgomery's change trends indicate a higher percentage of urban development than in the tricounty area.

■ By extrapolating backwards to 1986 using high resolution data from 2001 along with trends from Landsat data, the City of Montgomery's urban area increased by and estimated 8%, while the tree cover declined by 6.1%, as did bare soil, 2%. Open space remained about the same with only .4% decline.

■ An analysis of high resolution data shows that in 2002, the city is comprised of 33,620 acres of tree canopy (34%), 32,187 acres of open space (32%), 21,285 acres of impervious surfaces (21%), 11,307 acres of bare soil (11.3%), and 1,681 acres of water (1.7%).

■ As of 2002, the City of Montgomery's ecosystem services provided 227 million cubic ft. in stormwater services, valued at $454 million and removed 3.2 million lbs. of air pollutants, valued at $7.9 million.

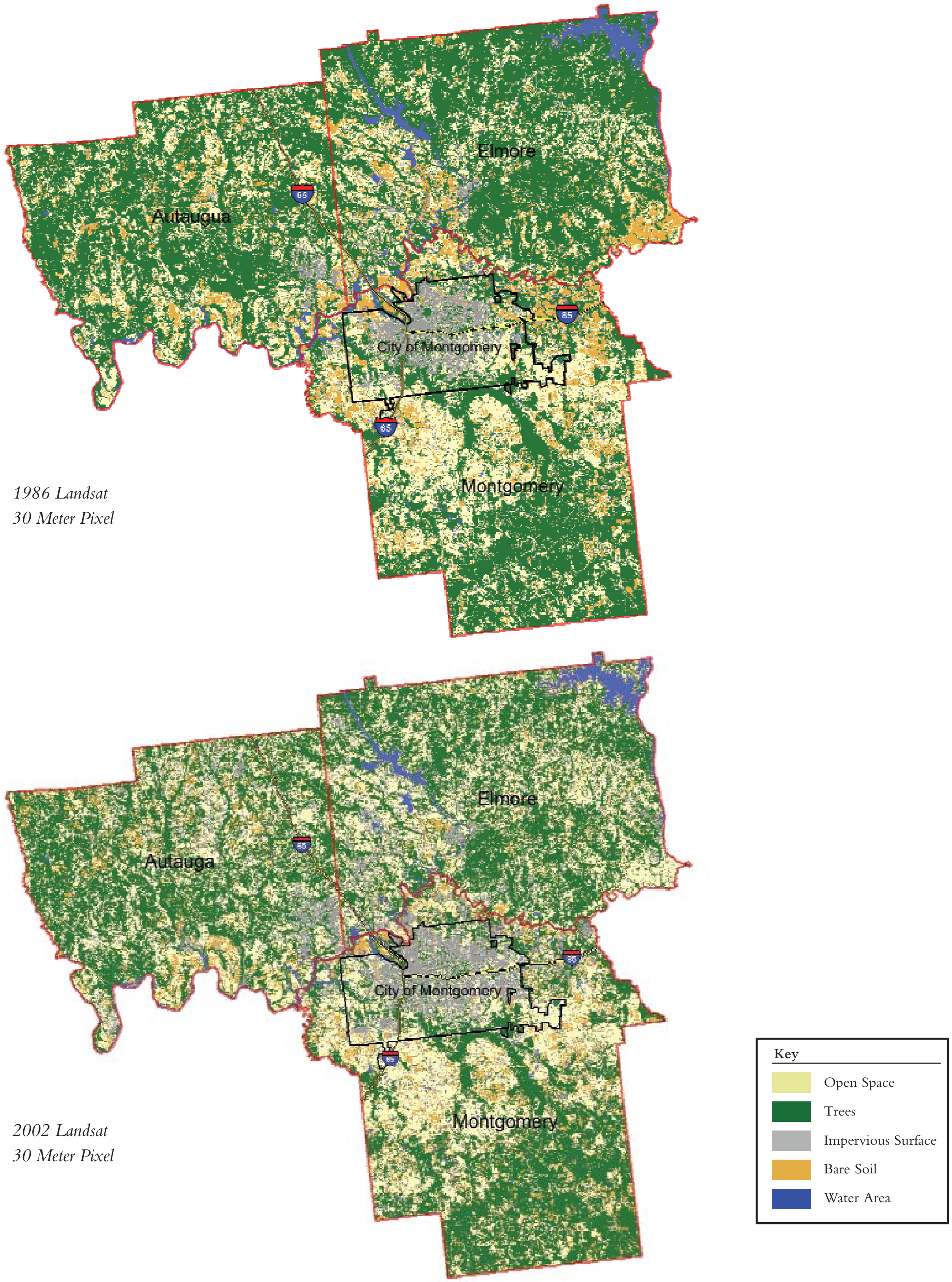
■ The city's trees sequestered 11, 263 tons annually and stored a total of 1.45 million tons of carbon.[3]

■ Nine of ten water quality contaminants would worsen by 9-38% if trees were removed from the land.[4] These percentages are calculated from the stormwater runoff changes.

Notes (see page 8)

[1] *Stormwater- formulas provided by the Natural Resource Conservation Service's TR-55 model.*
[2] *Air pollution mitigation formulas provided by USDA Forest Service's UFORE model.*
[3] *Carbon storage and sequestration rates provided by USDA Forest Service.*
[4] *Water quality formulas provided by Purdue University and US EPA's L-thia model.*

Temporal Landcover Change Trends

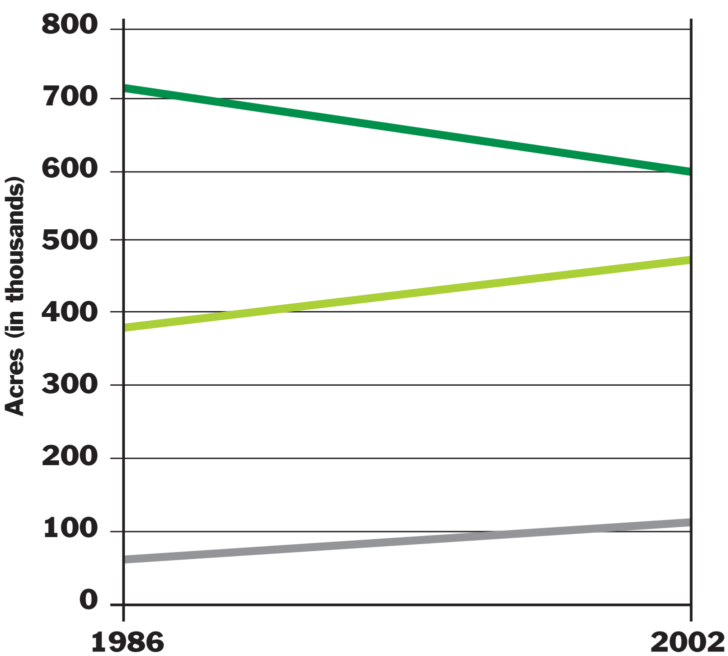


The classified Landsat images in Montgomery, Elmore and Autauga Counties illustrate landcover changes between 1986 and 2002.

Landsat satellites have been in orbit around the Earth since 1972 and data from them allow us to look at changes in landcover over time. AMERICAN FORESTS classified Landsat TM satellite images to show the change in tree cover for Montgomery, Elmore and Autauga Counties over a 16-year period. The analysis assessed the loss of tree canopy between 1986 and 2002.

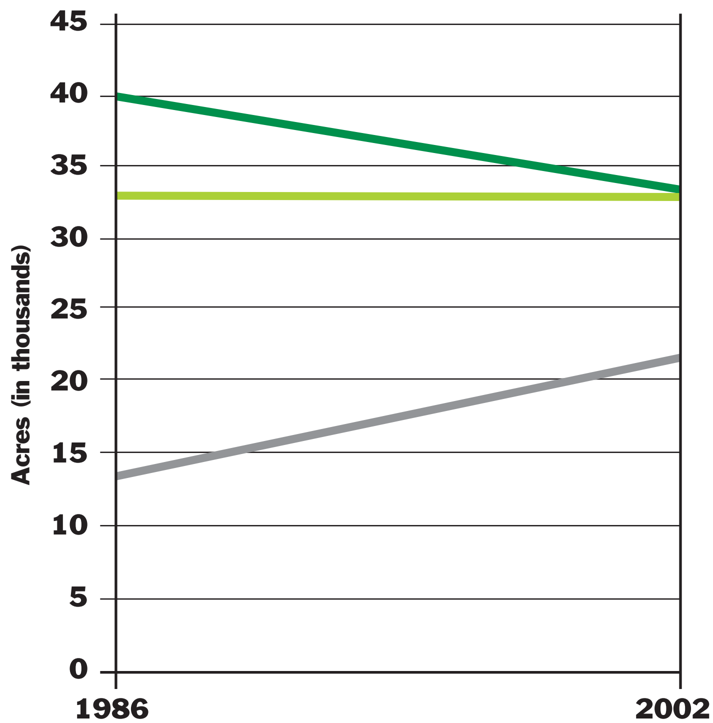
The Landsat images on page 4 provide valuable public policy information showing general trends in tree loss, but do not provide high-resolution data for local planning and management activities. High-resolution imagery (like that which is used in this study) produces a 4-meter or better resolution (compared to 30 meter with Landsat) and typically shows more tree canopy as seen in the tree cover in City of Montgomery (see pages 6-7). Since high resolution data did not exist in 1986, canopy change trends were estimated using the same percentages as were found in the Landsat data and were applied to the high resolution data.

Landcover Change Trend
Montgomery, Elmore and Autauga Counties
1986-2002

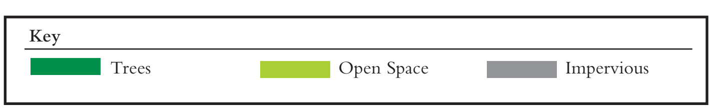


Landsat Data

Landcover Change Trend
City of Montgomery, AL
1986-2002



High Resolution Data (projected)



Graphing Change

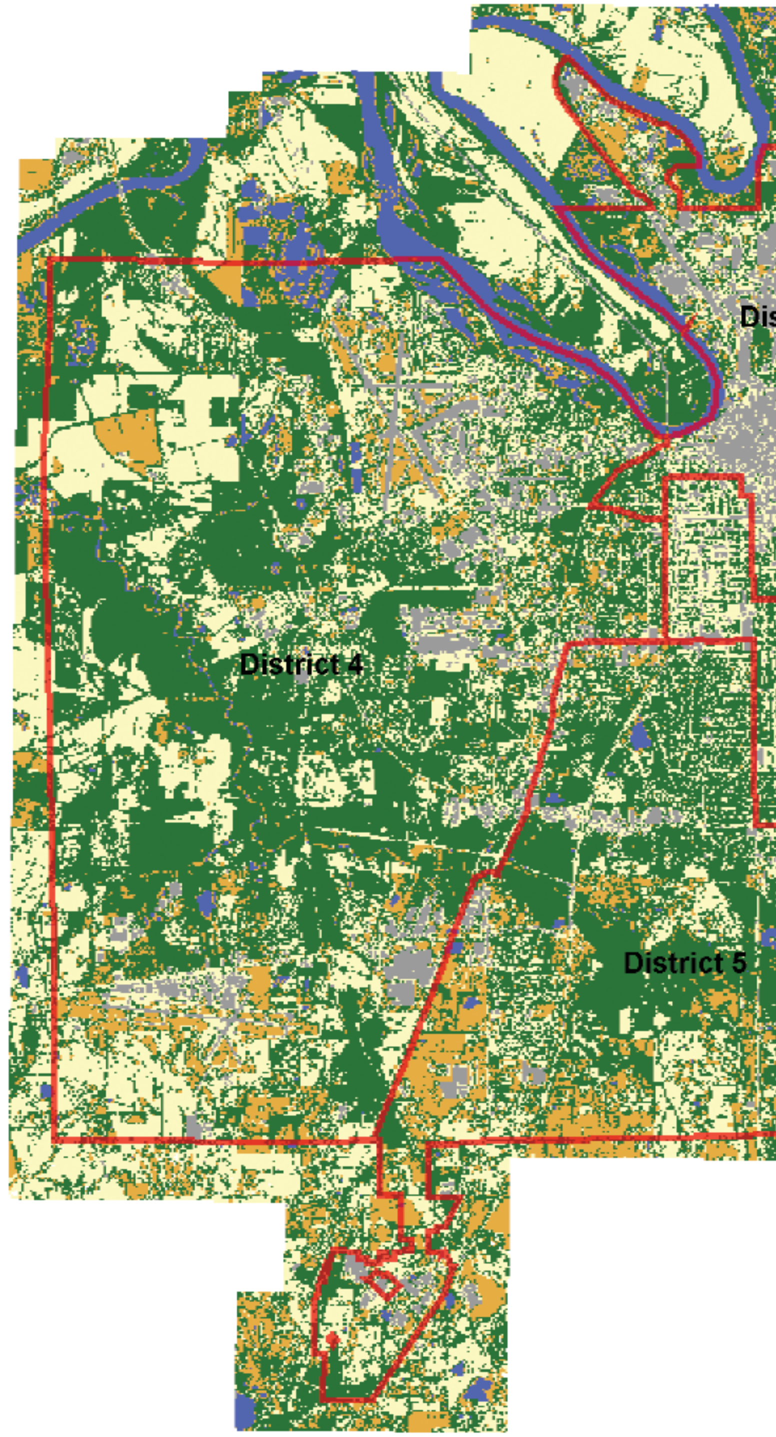
The change in vegetation depicted in the satellite images on page 4 is represented in line graphs above. The graph shows the change in landcover over a 16-year period for three categories. In the tricounty area the graph shows an increase in development and the loss of tree canopy and open space between 1986 and 2002. In the city of Montgomery tree canopy declined, impervious surface increased, and open space remained about the same.The dark green line represents tree cover. Developed areas (streets, buildings, parking lots, etc.) are represented by a gray line. The light green line represents vegetated open space (grass, scattered trees, etc.).

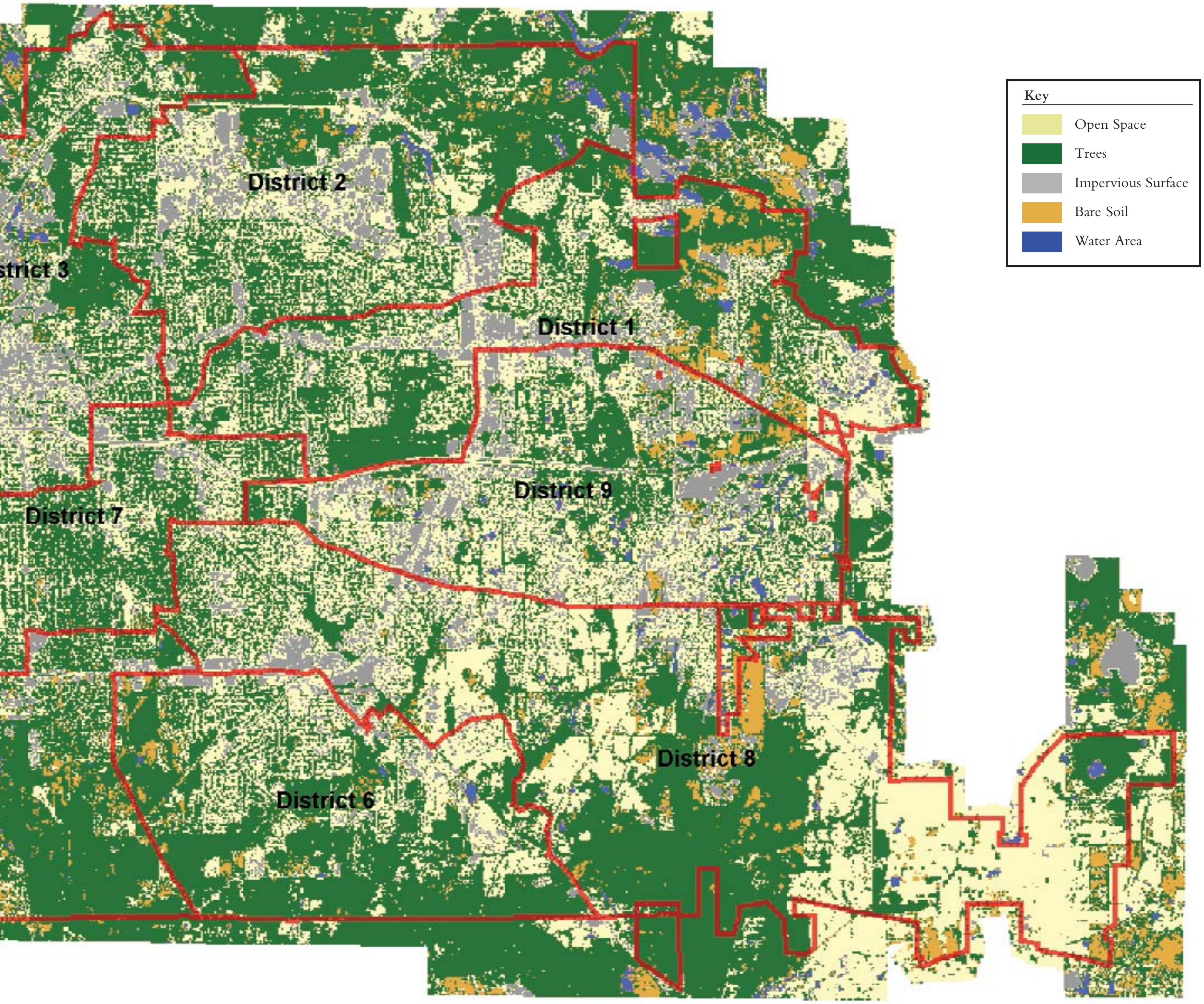
Creating a Green Data Layer for the City of Montgomery

While Landsat images provides good tree canopy trend information over time, its low resolution only shows trees in clumps the size of a Wal-Mart. The higher resolution imagery, with a four meter pixel ground resolution, shows trees as small as those with a six foot diameter canopy. Not only can the urban forest be seen more clearly, but this imagery allows for a more complete analysis of tree cover. After this imagery is classified into different land covers by GIS analysts, this digital data—or "green data layer" is used with CITYgreen to calculate the environmental and economic ecosystem services of the City of Montgomery. The data and tools are ready for the city staff to incorporate into their daily decisons.

The data produced for this study are flexible enough to be used in almost any way imaginable, along any boundaries—be they political or natural. From analyzing the value of trees within each council district tract to assessing the tree cover by subwatershed, the data are useful to those who work on planning, stormwater management, water quality, and urban forestry. The Galbraith Mill Creek Subwatershed and Council District 3, both of which encompass the downtown redevelopment area, have the least tree canopy cover and the greatest amount of impervious surface.

Though this report provides valuable information regarding the tree cover and its benefits for the city as a whole, the true strength of this project is in the data it provides for additional analyses as needed for local planning. With the land cover data set and CITYgreen software, the City of Montgomery now has the tools to put trees into the decision making process. For example city staff can over lay land use onto this green data layer to look for ways of increasing tree canopy in open space and vacant lots as the land is redeveloped.





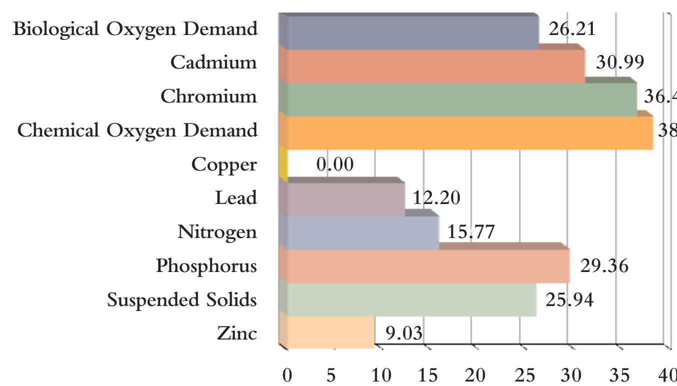
Classified High Resolution Data by City Council District

A high-resolution classified image of the City of Montgomery by City Council District and subwatershed highlighting different land covers.

Ecosystem Services Provided by Trees

Trees are indicators of a community's ecological health. While urban ecology is more complex than just tree cover, trees are good indicators of the health of an urban ecosystem. When trees are large and healthy, the ecological systems—soil, air and water—that support them are also healthy. In turn, healthy trees provide valuable environmental benefits. The greater the tree cover and the less the impervious surface, the more ecosystem services are produced in terms of reducing stormwater runoff, increasing air and water quality, storing and sequestering atmospheric carbon and reducing summer temperatures. The ecosystem services quantified in this study include:

Percent Change in Water Contaminant Loadings



Trees and Water

Stormwater Runoff Reduction

Trees and soils function together to reduce stormwater runoff. Trees reduce stormwater flow by intercepting rainwater on leaves, branches, and trunks. Some of the intercepted water evaporates back into the atmosphere and some soaks into the ground reducing the total amount of runoff that must be managed in urban areas. Trees also slow storm flow, reducing the volume of water that a containment facility must store. For example, using 2002 high resolution data, the City of Montgomery's existing 34% tree canopy reduced the need for retention structures by 227 million cubic feet, valued at $454 million per 20-year construction cycle (based on a $2/cubic foot construction cost).

Water Quality

When stormwater hits impervious surfaces in urban areas, it increases the water temperature and also picks up various pollutants, every thing from excess lawn fertilizers to oils on roadways. This translates into water quality problems when large volumes of heated stormwater flow into receiving waters, posing threats to temperature sensitive species, such as trout and small invertebrates, as well as providing conditions for algal blooms and nutrient imbalances.

Federal Clean Water Act regulations issued under Stormwater–Phase I and II provided cities with opportunities to incorporate trees into specific environmental practices. Tree cover helps intercept rainwater, thus reducing the amount, and speed, of stormwater along with filtering pollutants that eventually flow to receiving waters. Ten water pollutants (contaminant loadings listed above) are assessed by the L-Thia spreadsheet model that measures specific pollutants in stormwater runoff during a storm event. In the city of Montgomery, nine of the ten water contaminants measured increased when comparing the city's current tree canopy to a no tree canopy condition.

Trees and Air Quality

Even though the region currently meets clean air quality standards, the burning of fossil fuels continues to add a steady flow of deadly pollutants into our atmosphere. Trees remove many pollutants from the atmosphere, including nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), and particulate matter of ten microns or less (PM10).

The analysis uses Dr. David Nowak's, USDA Forest Service, formulas from research in 55 U.S. cities to assess the air pollution removal capacity of urban forests with respect to the above pollutants. Economists multiply the number of tons of pollutants by an "externality" cost—that is a cost that society would have to pay in areas such as health care, if trees did not remove these pollutants. Dollar values for pollutants are based on the externality costs set by the Public Service Commission in each state. The City of Montgomery's urban forest removes 3,206,700 lbs. of pollutants each year, an annual value of $7,894,000.

Trees and Carbon

In addition to improving air quality, trees are able to absorb atmospheric carbon, which reduces greenhouse gases and thought to contribute to global warming.

The carbon related function of trees is measured in two ways: storage or the total amount currently stored in tree biomass, and sequestration, the rate of absorption per year. Tree age greatly affects the ability to store and sequester carbon. Older trees store more total carbon in their wood and younger trees sequester more carbon annually. The city's trees currently store 1.4 million tons of carbon and sequester 11,000 tons annually. Currently there is no economic measurement of the value of carbon sequestration in the U.S. However, international markets are trading carbon credits today and these may also be traded in the U.S. before too long.

Table 1. 2002 Ecosystem Services of Trees by City Council District

Name	Acres	Tree Canopy	Stormwater Management Value (cu.ft.)	Stormwater Management Value* ($)	Air Pollution Annual Removal Value (lbs.)	Air Pollution Annual Removal Value ($)	Carbon Stored (tons)	Carbon Sequesterd Annually (tons)
District 1	8,796	36%	20,045,938	$40,091,875	300,593	$740,012	135,614	1,056
District 2	10,125	37%	24,155,211	$48,310,422	356,012	$876,446	160,616	1,250
District 3	7,662	26%	16,441,963	$32,883,927	188,959	$465,188	85,250	664
District 4	23,015	34%	47,113,583	$94,227,167	745,019	$1,834,120	336,119	2,617
District 5	12,330	38%	28,644,091	$57,288,181	444,057	$1,093,199	200,338	1,560
District 6	7,618	43%	18,106,536	$36,213,072	310,966	$765,550	140,294	1,092
District 7	4,560	37%	10,113,776	$20,227,551	160,319	$394,681	72,329	563
District 8	16,970	31%	32,500,228	$65,000,455	508,290	$1,251,330	229,317	1,785
District 9	8,891	22%	17,026,887	$34,053,773	187,584	$461,803	84,629	659

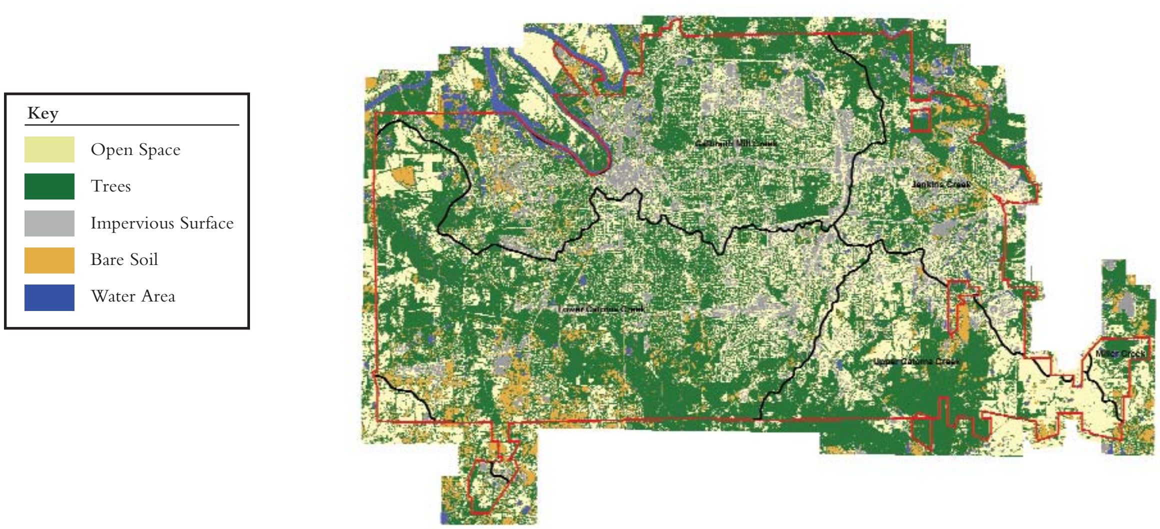
*based on $2 per cubic foot mitigation cost

Table 2. 2002 Ecosystem Services of Trees by Subwatershed*

Name	Acres	Tree Canopy	Stormwater Management Value** (cu.ft.)	Stormwater Management Value* ($)	Air Pollution Annual Removal Value (lbs.)	Air Pollution Annual Removal Value ($)	Carbon Stored (tons)	Carbon Sequesterd Annually (tons)
Galbraith Mill Creek	29,471	29%	60,329,620	$120,659,240	825,132	$2,031,345	372,262	2,898
Jenkins Creek	13,326	31%	30,253,015	$60,506,030	394,118	$970,257	177,808	1,384
Lower Catoma Creek	39,780	37%	85,368,871	$170,737,742	1,410,308	$3,471,956	636,267	4,954
Miller Creek	1,213	29%	1,980,274	$3,960,547	33,251	$81,859	15,001	117
Upper Catoma Creek	14,912	37%	30,018,183	$60,036,367	523,331	$1,288,358	236,103	1,838

*Subwatersheds are 11-digit hydrologic units; the data was prepared by the Alabama Geologic Survey.

**based on $2 per cubic foot mitigation cost



Classified High Resolution Data by Subwatershed

Recommendations

This study provides a detailed assessment of the tree cover in 2002 and quantifies ecological benefits for Montgomery, Autauga, and Elmore Counties and the City of Montgomery. While this project provides a snapshot of tree cover and the ecosystem services it provides, the greatest value of this project is for the "green data layer" (digital data) and tools to be used to implement the goals stated in the *City of Montgomery's Comprehensive Urban Forestry Plan (2002)*. Using the green data layer provides the basis for future planning and goal-setting; regulation of development and construction practices; and urban forestry operations (tree maintenance and removals, tree planting, and public education).

The data from this analysis can be used on a daily basis and is available at no cost to communities in the study area. Each community can improve their decision making by using this data in every day real world activity. The City of Montgomery recently hired its first urban forester, an act that demonstrates its commitment to its urban forest.

1. Form an "ad hoc steering committee" to study the findings and recommendations of the Urban Ecosystem Analysis and develop strategies to implement the results.

■ City of Montgomery Planning Department, with assistance from the Montgomery Tree Committee, will select and convene a steering committee of local government, business, and citizen representatives (i.e. urban forester, city planner, citizen activist, public educator, public relations person, local business person, GIS technician).

■ Steering committee to develop a graphic presentation format (i.e. slide show, portfolio, graphic poster board) from the report and present the urban ecosystem analysis to local government departments, elected officials, and citizen groups in the tricounty area.

2. Integrate the green data layer into other municipal GIS systems.

■ Steering committee to collaborate with City of Montgomery's Planning Department to study how digital green data layer and related software (i.e. CITY green) can be utilized within existing city departments.

■ Steering Committee to use the City of Montgomery's green data layer and implementation strategies as a model to promote green infrastructure in other cities within the tricounty area.

■ Local urban governments within Montgomery, Autauga, and Elmore Counties are encouraged to acquire a green data layer (classified, high resolution digital data) so that they can conduct their own urban ecosystem analyses to make better-informed planning decisions.

3. Satisfy clean water regulations and increase funding opportunities by recognizing that trees provide ecosystem services.

■ City of Montgomery to set canopy cover targets, goals, and strategies as a means of complying with federal and state air and water quality standards.

■ City of Montgomery to encourage Alabama Department of Environmental Management to recognize and promote tree canopy as a best management practice to comply with federal clean air and water regulations (Stormwater Phase I and II).

■ City of Montgomery's urban forester to identify appropriate federal and state funding sources which allow urban forestry activities as a means of addressing air and water quality problems and issues (i.e. the U.S. Environmental Protection Agency). For example, developing a greenway along Cypress Creek not only provides links to neighborhoods and the river, but planting riparian vegetation is a Best Management Practice (BMP) for improving water quality flowing into the Alabama River and thus could qualify for federal grants.

4. Use the findings of this study to address public policy issues for land-use planning and growth management

■ City council is encouraged to adopt policies that integrate green infrastructure into all new and revised ordinances pertaining to urban planning, design, and maintenance so as to maximize tree growth potential and optimize their environmental and economic benefits.

■ Neighborhood Associations and city planners can increase the city's overall tree canopy percentage by engaging all sectors of the community and finding opportunities to plant trees in vacant lots, neglected lands, and downtown redevelopment projects.

■ In new development, urban planners are encouraged to create "green subdivisions" that provide sufficient space for larger trees. Use strategies such as Low Impact Design and Smart Growth practices that include clustering housing, narrowing streets, planting large groupings of large shade trees in common areas, strategically locating trees to maximize energy conservation around homes, and retain stormwater onsite to reduce peak flow that stormwater sewer systems must manage.

5. Raise public awareness and engage the public in becoming stewards of their urban forest

■ Steering committee to develop an outreach and public education plan to teach community groups about the environmental benefits of trees.

■ Neighborhood associations to promote tree planting and stewardship to improve citywide air and water quality and reduce household energy costs.

■ Public schools and local colleges to use CITYgreen software to teach ecology, geographic information systems, geography, and biology. They can fulfill community service projects with community tree planting.

6. Setting Tree Canopy Goals

AMERICAN FORESTS recommends that communities establish tree canopy goals tailored to their administrative geographic areas and then use CITYgreen to plan and manage their progress. AMERICAN FORESTS has provided the following generalized target goals for the eastern U.S., but realizes that every community is different and needs to set their own goals. Armed with this green data layer and CITYgreen software, communities can better assess their urban forest as a community asset and incorporate this green infrastructure into future planning.

■ AMERICAN FORESTS' General Tree Canopy Goals for the Montgomery Region
- 40% tree canopy overall
- 50% tree canopy in suburban residential
- 25% tree canopy in urban residential
- 15% tree canopy in central business districts

■ When setting goals, consider the unique soil type classifications in the tricounty area, especially in localized areas. For example, the Selma Chalk is a poorly drained, clayey, and high pH soil that limits tree selection choices and presents difficult challenges for planting.

■ Consider specific political and environmental boundary tree goals such as Council District 3, Galbraith Mill Creek, and the Riverfront redevelopment area and how to achieve increasing tree canopy in especially sensitive areas like those linked to waterways.

About the Urban Ecosystem Analysis

AMERICAN FORESTS Urban Ecosystem Analysis is based on the assessment of "ecological structures"—unique combinations of land use and land cover patterns. Each combination performs ecological functions differently and is therefore assigned a different value. For example, a site with heavy tree canopy provides more stormwater reduction benefits than one with lighter tree canopy and more impervious surface.

Data Used

For the temporal landcover analysis (page 4), Landsat Satellite TM (30 meter pixel) images were used as the source of landcover data. AMERICAN FORESTS used a knowledge-based classification technique to divide the landcover into five categories (water, trees, impervious surfaces, open space, and bare ground).

To create the green data layer, Ikonos, high-resolution (4 meter pixel) multispectral imagery was obtained. AMERICAN FORESTS used a knowledge-based classification technique to categorize different land covers such as trees, impervious surfaces, open space, bare ground and water. Classified Landsat imagery was resampled to 4 meters and used to fill in any gaps in the multispectral analysis (3% of total land area).

Analysis Formulas

CITYgreen analyses were conducted for Montgomery, Autauga and Elmore counties; the city of Montgomery; five subwatersheds in the city; city council districts; and the Riverfront Master Plan area. An Urban Ecosystem Analysis Report appendix detailing the ecological and economic findings of each area is available through the City of Montgomery Department of Planning).

CITYgreen for ArcGIS used the raster data land cover classification from the high-resolution imagery for the analysis. The following formulas are incorporated into CITYgreen software.

TR-55 for Stormwater Runoff: The stormwater runoff calculations incorporate formulas from the Urban Hydrology of Small Watersheds model, (TR-55) developed by the US Natural Resources Conservation Service (NRCS), formerly known as the U.S. Soil Conservation Service. Don Woodward, P.E., a hydrologic engineer with NRCS, customized the formulas to determine the benefits of trees and other urban vegetation with respect to stormwater management.

L-Thia for Water Quality: Using values from the U.S. Environmental Protection Agency (EPA) and Purdue University's L-thia spreadsheet water quality model, The Natural Resources Conservation Service (NRCS) developed the CITYgreen water quality model. This model estimates the change in the concentration of the pollutants in runoff during a typical storm event given the change in the land cover from existing trees to a no tree condition. This model estimates the event mean concentrations of nitrogen, phosphorus, suspended solids, zinc, lead, copper, cadmium, chromium, chemical oxygen demand (COD), and biological oxygen demand (BOD). Pollutant values are shown as a percentage of change.

UFORE Model for Air Pollution: CITYgreen® uses formulas from a model developed by David Nowak, PhD, of the USDA Forest Service. The model estimates how many pounds of ozone, sulfur dioxide, nitrogen dioxide, and carbon monoxide are deposited in tree canopies as well as the amount of carbon sequestered. The urban forest effects (UFORE) model is based on data collected in 55 U.S. cities. Dollar values for air pollutants are based on averaging the externality costs set by the State Public Service Commission in each state. Externality costs, are the indirect costs to society, such as rising health care expenditures as a result of air pollutants' detrimental effects on human health.

Acknowledgements for this Study
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For More Information
AMERICAN FORESTS, founded in 1875, is the oldest national nonprofit citizen conservation organization. Its three centers–Global ReLeaf, Urban Forestry, and Forest Policy–mobilize people to improve the environment by planting and caring for trees.

AMERICAN FORESTS' CITYgreen® software provides individuals, organizations, and agencies with a powerful tool to evaluate development and restoration strategies and impacts on urban ecosystems. AMERICAN FORESTS offers regional training workshops and technical support for CITYgreen® and is a certified ESRI developer and reseller of ArcView and ArcGIS products. For further information contact:

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